US-PAT-NO: 5794187

DOCUMENT-IDENTIFIER: US 5794187 A

TITLE: Method and apparatus for improving effective signal to noise ratios in hearing aids and other communication systems used in noisy environments without loss of spectral information

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Abstract Text - ABTX (1):

Improved signal to noise ratio to help speech comprehension in a noisy environment is accomplished by selectively downwardly expanding a speech and noise composite signal when the speech signal is absent, thereby lowering signal components which represent noise. An expansion control signal is extracted from the composite input signal. Operation is based on the assumption that when noise alone is present, the input signal amplitude is less than some reference level and that when speech and noise are present together, the input signal amplitude is greater than the reference level. The response rates of gain changes are quite rapid, and do not introduce distortion or other audibly noticeable artifacts of the processing. The amount of downward expansion of the noise alone is small compared to noise gates to further reduce processing artifacts. The methods of realization include use of, in combination and alone, analog compressors and expanders, analog expanders in combination with voltage clamps and/or automatic level control circuits, two-quadrant multipliers in conjunction with digital control, entirely digital means for obtaining the requisite sensing and gain control, and expandor designs that are analogs of conventional filter designs where the notion of amplitude replaces frequency. Automatic noise suppression may be employed to pre-process the input signal, thereby rendering the control circuit self adjusting for better performance over a wide range of background sound levels. Various microphone, preferably providing directional characteristics, may be used to reduce noise levels in the received input signal.

Brief Summary Text - BSTX (3):

The present invention pertains to a method and apparatus for enhancing the effective signal to noise ratio of hearing assistive devices and other communication systems utilized in noisy environments without loss of spectral information. The enhanced effective signal to noise ratio enables improved comprehension of speech and reduced stress levels for a particular user of the hearing assistive device or communication system.

Brief Summary Text - BSTX (5):

Listening to speech in a noisy environment complicates speech comprehension and increases stress levels for particular listeners. These effects are especially prevalent for listeners suffering from significant hearing loss. Current methods to reduce the amount of stress and improve speech comprehension in noisy environments attempt to enhance the effective signal to noise ratio by elevating the desired speech above background noise. The elevated speech enables listeners to more easily discern speech from noise and therefore comprehend speech with reduced stress. These methods are generally employed in various systems and either attempt to bias against the quantity of noise received by the system in comparison with the quantity of the desired speech signal, or introduce processing that deletes some portion of the noise while retaining as much of the desired speech signal as possible.

Brief Summary Text - BSTX (6):

Several major methods are currently being employed to decrease the noise in hearing assistive devices and various communication systems. Specifically, first order directional microphones are typically employed in order to reduce noise emanating from directions other than that of the desired talker or sound source. Second order directional microphones generally outperform both first order directional and omnidirectional microphones by wide margins, but are difficult to realize in hearing aids as discussed below.

Brief Summary Text - BSTX (11):

The prior art noise reduction methods suffer from several disadvantages. The utilization of second order directional microphones to achieve improvements over omnidirectional microphones incurs significant monetary costs. Further, second order directional microphones are more complex and tend to have reduced performance in relation to certain other signal reception categories. In particular, second order microphones tend to be noisier than omnidirectional microphones and have a twelve decibel per octave (db/octave) decrease in output level as frequency declines. First order microphones are inadequate as they provide insufficient noise rejection to be effective, typically on the order of a three to four decibel or less improvement over omnidirectional microphones depending upon the application. This is particularly true when the microphones are mounted at ear-level, which is the usual placement for modern hearing aids, because the so-called "head-shadow" effect tends to further decrease the advantages of first order microphones as compared to omnidirectional elements.

Brief Summary Text - BSTX (18):

It is another object of the present invention to use electronic circuits in conjunction with directional or omnidirectional microphones to enhance the level of desired speech signal components within received speech signal waveforms by more effectively rejecting ambient noise components.

Brief Summary Text - BSTX (25):

A further object of the present invention is to improve speech comprehension in noisy environments by providing an apparatus for reducing noise and enhancing the effective signal to noise ratio of the speech in combination with an automatic noise suppressor such that the noise reduction property of the apparatus is self-adapting according to the level of background noise and does not introduce undesirable distortions into a speech signal waveform.

Brief Summary Text - BSTX (40):

To some extent both of these requirements are met by utilizing a directional microphone aimed towards the desired speaker. This strategy taken together with an inherent tendency for talkers to speak louder in noise (i.e., the "Lombard Effect") suffices in many, but not all, situations such that the invention behaves as it should. That is to say, by judicious and careful design of the gain characteristics of the microphone and first amplifiers of such a system, one can assure that most of the time, in most situations, the noise and speech appear at the input to the control circuit at appropriate levels such that operation proceeds as desired.

Drawing Description Text - DRTX (2):

FIG. 1 is a schematic diagram of a circuit for enhancing the effective signal to noise ratio of speech in hearing assistive devices and other communication systems according to the present invention utilizing the combination of a modified compressor circuit followed by a modified expandor circuit.

Detailed Description Text - DETX (2):

One general configuration of a circuit embodiment of the present invention for enhancing the effective signal to noise ratio of hearing assistive devices and other communication systems in a noisy environment is illustrated in FIG. 1. Specifically, directional microphone 101 receives a composite speech signal waveform, typically including desired speech signal components and noise components and applies the waveform to a conventional preamplifier 105. The amplified waveform is applied through a capacitor 106 to modified amplitude compressor 117. Modified compressor 117 (i.e., modified from conventional compressors in accordance with the present

invention) selectively compresses portions of the composite waveform amplitude pursuant to a non-linear compression function and is controlled by a compression control signal and bias or threshold level as described below. The compression control signal is extracted from the input signal and is a function of the presence and absence of the desired speech signal components as determined by input signal amplitude as discussed below. The amplitude-compressed waveform is subsequently applied through a coupling capacitor 128 to a modified amplitude expandor 129. Modified expandor 129 (i.e., modified from conventional expanders in accordance with the present invention) selectively expands portions of the compressed waveform amplitude pursuant to a non-linear expansion function which is substantially a dual function of the non-linear compression function performed in compressor 117. The expansion function is controlled by an expansion control signal and bias or threshold level as described below. The expansion control signal is a function of the presence and absence of speech signal components in the signal applied to the expandor in the presence of such components being again determined by the magnitude of the expandor input signal as described below. The resulting expanded waveform is a modified version of the original input waveform received by microphone 101 with an improved effective signal to noise ratio. The expanded waveform is applied through a coupling capacitor 142 across a level control 143. Level control 143, typically a variable resistor, permits adjustment of the level of the expanded waveform and applies the expanded waveform to post-amplifier 161. The amplified waveform is applied to a headset 171, or the like, for conveying processed sound from the enhanced composite waveform to a listener.

Detailed Description Text - DETX (6):

There are several known techniques for improving the signal to noise ratio in deriving the compression control signal, including the use of a directional microphone for receiving the composite waveform (i.e., desired speech signal and noise). The directional microphone is aimed at the speech source such that the noise is received in a diffuse manner with reduced energy as compared to the speech signal. This technique improves the signal to noise ratio for both the compression control signal and the received composite input waveform.

Detailed Description Text - DETX (26):

It will be appreciated that the embodiments described above and illustrated in the drawings represent only a few of the many ways of implementing an enhanced effective signal to noise ratio for speech in noisy environments.

Detailed Description Text - DETX (28):

The technique of effective signal to noise ratio enhancement of

the present invention may be applied to systems utilizing a microphone, plurality of microphones, or other signal reception device in conjunction with electronic amplification for delivery of the enhanced speech signals to a listener, plurality of listeners, or a computer interface. Further, the present invention may be used in several applications including but not limited to: small wearable systems (i.e. hearing aids, tactile aids, cochlear implants and/or other hearing assistive devices), conference-microphone systems, and automatic speech recognition systems showing degraded performance in the presence of noise.

Detailed Description Text - DETX (29):

The microphones may be any conventional or other type microphone or device capable of receiving an acoustic input signal waveform and transducing it to an electrical audio signal. The operational amplifiers may be any commercially available operational amplifiers or equivalent circuit capable of amplifying a signal. The variable voltage controlled resistors (i.e., gain cells) may be any voltage or current controlled resistors or device capable of adjusting resistance. The resistors and capacitors may be conventional electronic components or combinations of the electronic components yielding the same electrical properties. Further, the diodes may be conventional diodes or other electrical devices limiting current flow or threshold voltage. The preamplifier and post-amplifiers may be conventional amplifiers or other equivalent circuits for amplifying signals. The headset may be any conventional headset or other device capable of conveying the enhanced speech signal waveform to a listener.

Detailed Description Text - DETX (31):

From the foregoing description it will be appreciated that the invention makes available a novel method and apparatus for enhancing the effective signal to noise ratio of hearing assistive devices or communication systems implemented in noisy environments wherein a signal waveform is selectively expanded downward by a small amount by adjusting the gain of a circuit based upon the level of an input signal, and by means of a control signal extracted from the input signal.

Detailed Description Text - DETX (32):

Having described preferred embodiments of the new and improved method and apparatus for enhancing the effective signal to noise ratio of hearing assistive devices and communication systems implemented in noisy environments, it is believed that other modifications, variations and changes will be suggested to those skilled in the art in view of the teachings set forth herein. It is therefore to be understood that all such variations, modifications

and changes are believed to fall within the scope of the present invention as defined by the appended claims.

Claims Text - CLTX (1):

1. A signal enhancement apparatus for use in communication systems to enhance the effective signal to noise ratio of speech in a noisy environment without loss of spectral information and without introducing distortion into said speech, wherein amplitudes of said speech below a predetermined threshold are considered to be noise while amplitudes above the threshold are considered to be desired speech, said apparatus comprising:

Claims Text - CLTX (53):

21. A signal enhancement apparatus for use in communication systems to enhance the effective signal to noise ratio of speech in a noisy environment without loss of spectral information and without introducing distortion into said speech, wherein amplitudes of said speech below a predetermined threshold are considered to be noise while amplitudes above the threshold are considered to be desired speech, said apparatus comprising:

Claims Text - CLTX (60):

22. A signal enhancement apparatus for use in communication systems to enhance the effective signal to noise ratio of speech in a noisy environment without loss of spectral information and without introducing distortion into said speech, wherein amplitudes of said speech below a predetermined threshold are considered to be noise while amplitudes above the threshold are considered to be desired speech, said apparatus comprising:

Claims Text - CLTX (66):

23. In a signal enhancement apparatus for use in communication systems, a method to enhance the effective signal to noise ratio of speech in a noisy environment without loss of spectral information and without introducing distortion into said speech, wherein amplitudes of said speech below a predetermined threshold are considered to be noise while amplitudes above the threshold are considered to be desired speech, said method comprising the steps of:

Claims Text - CLTX (108):

40. In a signal enhancement apparatus for use in communication systems, a method to enhance the effective signal to noise ratio of speech in a noisy environment without loss of spectral information and without introducing distortion into said speech, wherein

amplitudes of said input speech signal waveform below a predetermined threshold are considered to be noise while amplitudes above the threshold are considered to be desired speech, said method comprising the steps of:

Claims Text - CLTX (115):

41. In a signal enhancement apparatus for use in communication svstems, a method to enhance the effective signal to noise ratio of speech in a noisy environment without loss of spectral information and without introducing distortion into said speech, wherein amplitudes of said input speech signal waveform below a predetermined threshold are considered to be noise while amplitudes above the threshold are considered to be desired speech, said method comprising the steps of:

Field of Search Class/SubClass - FSCS (6):

381/68